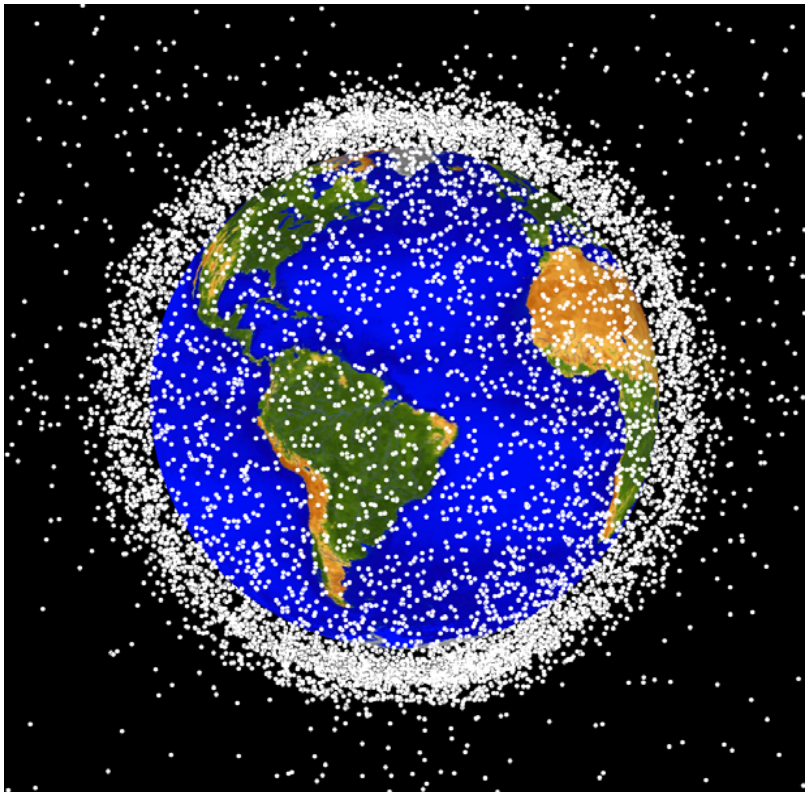
National Aeronautics and Space Administration

Orbital Debris Mitigation



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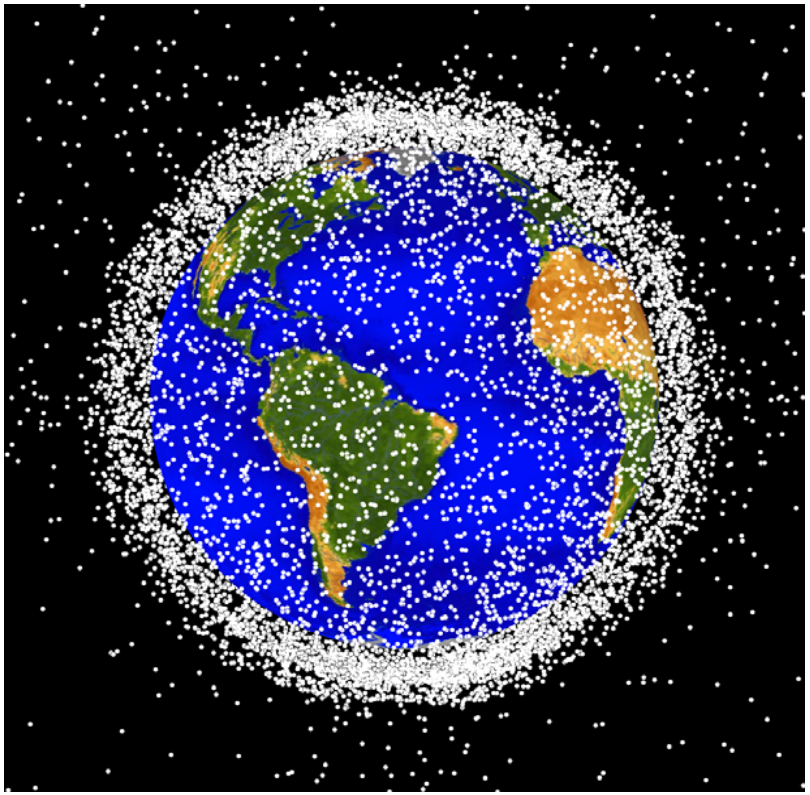
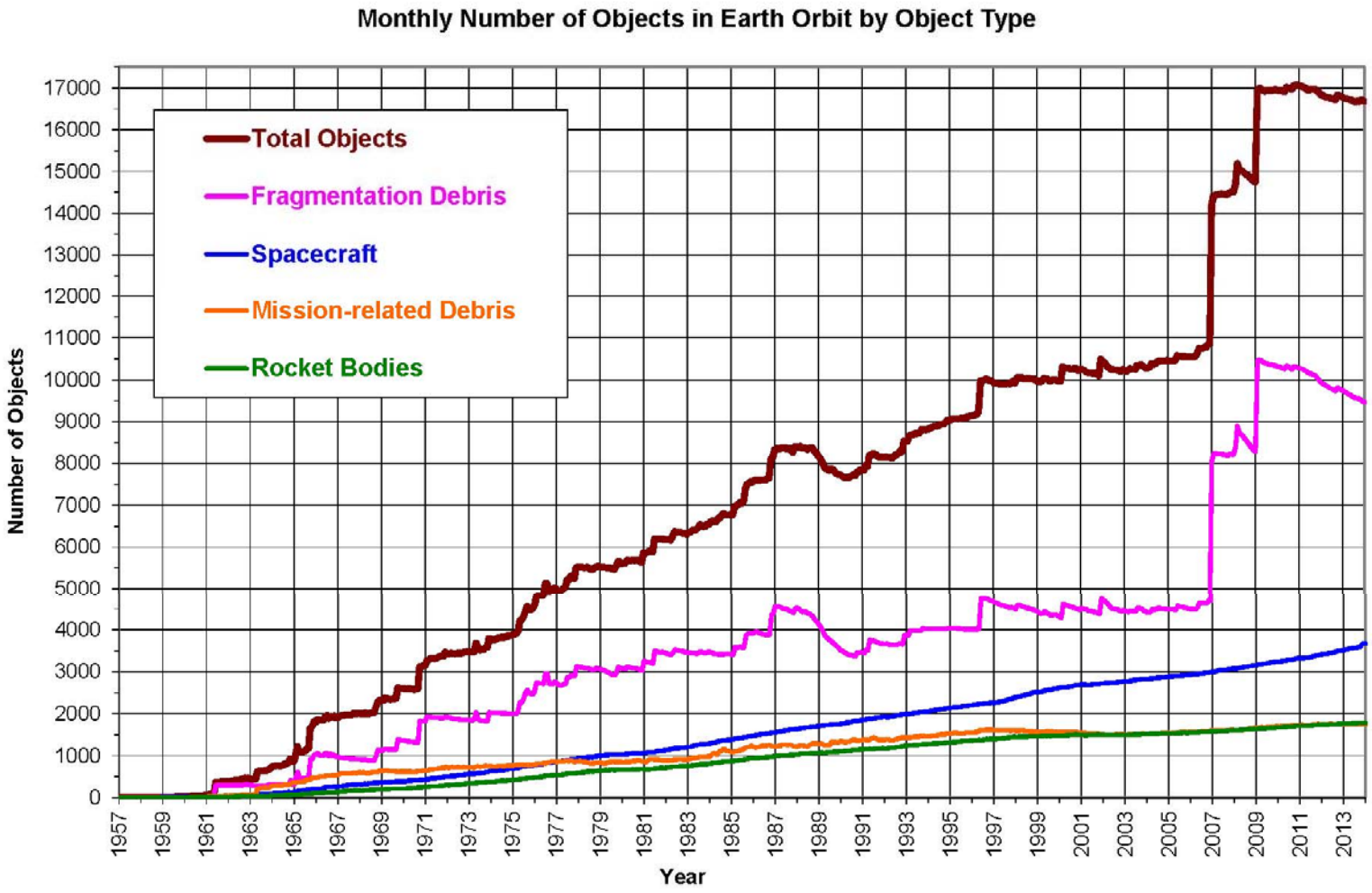
Outline

- **Description of Current Orbital Debris Environment**
- **NPR and NS**
- **DAS**

The Orbital Debris Environment

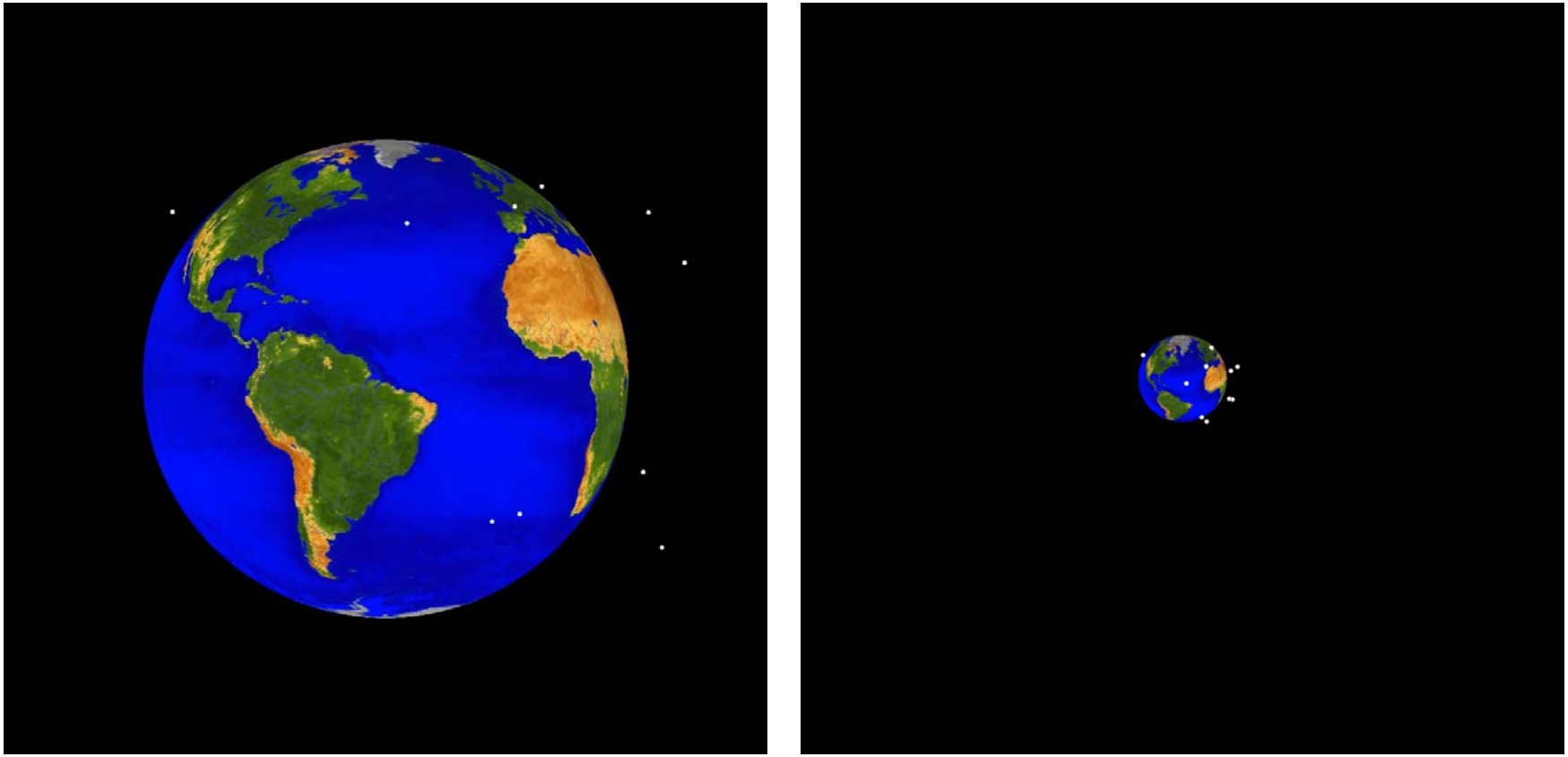


Evolution of the Cataloged Satellite Population



Growth of the Earth Satellite Population

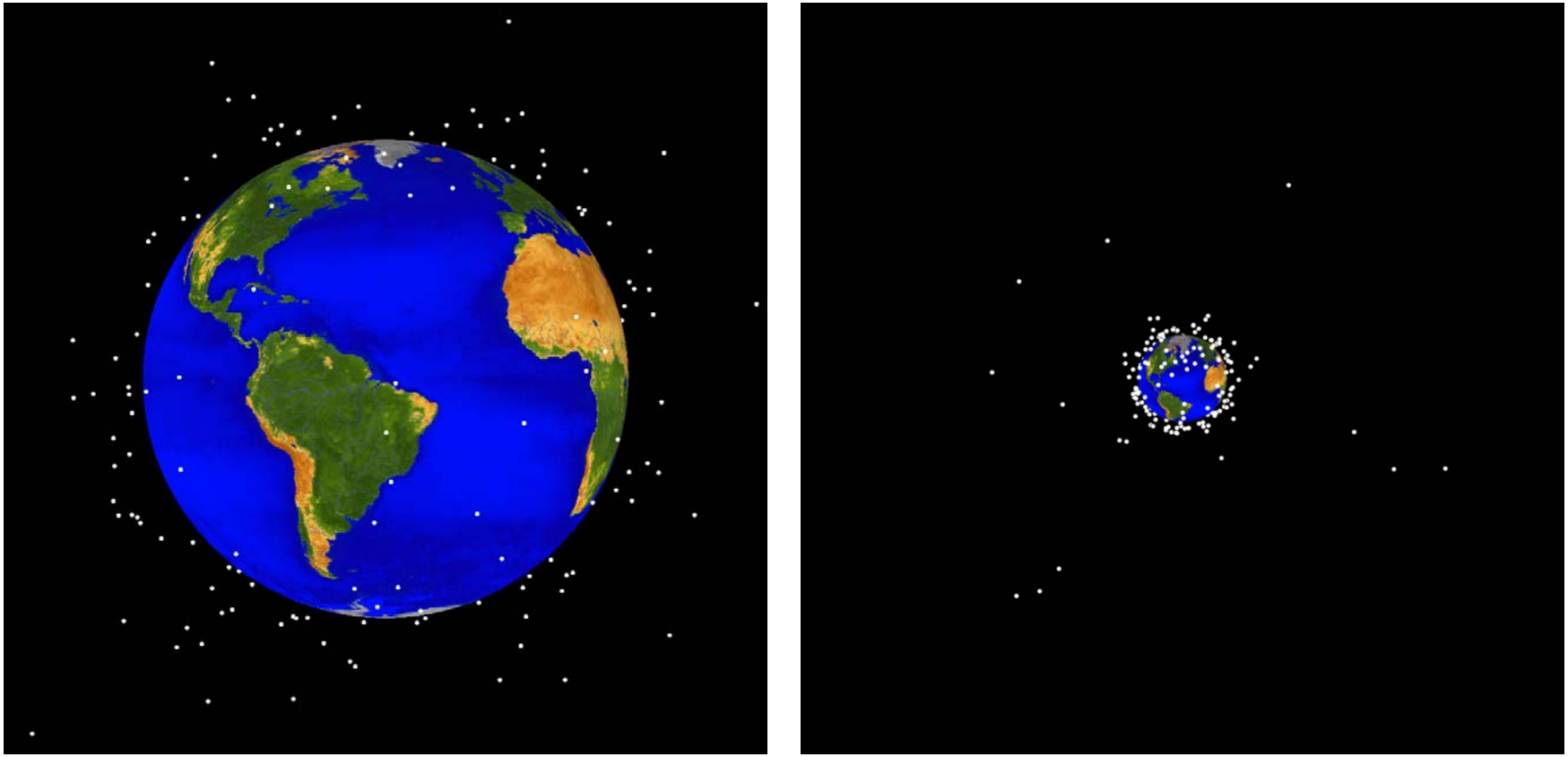
1960



Cataloged objects >10 cm diameter

Growth of the Earth Satellite Population

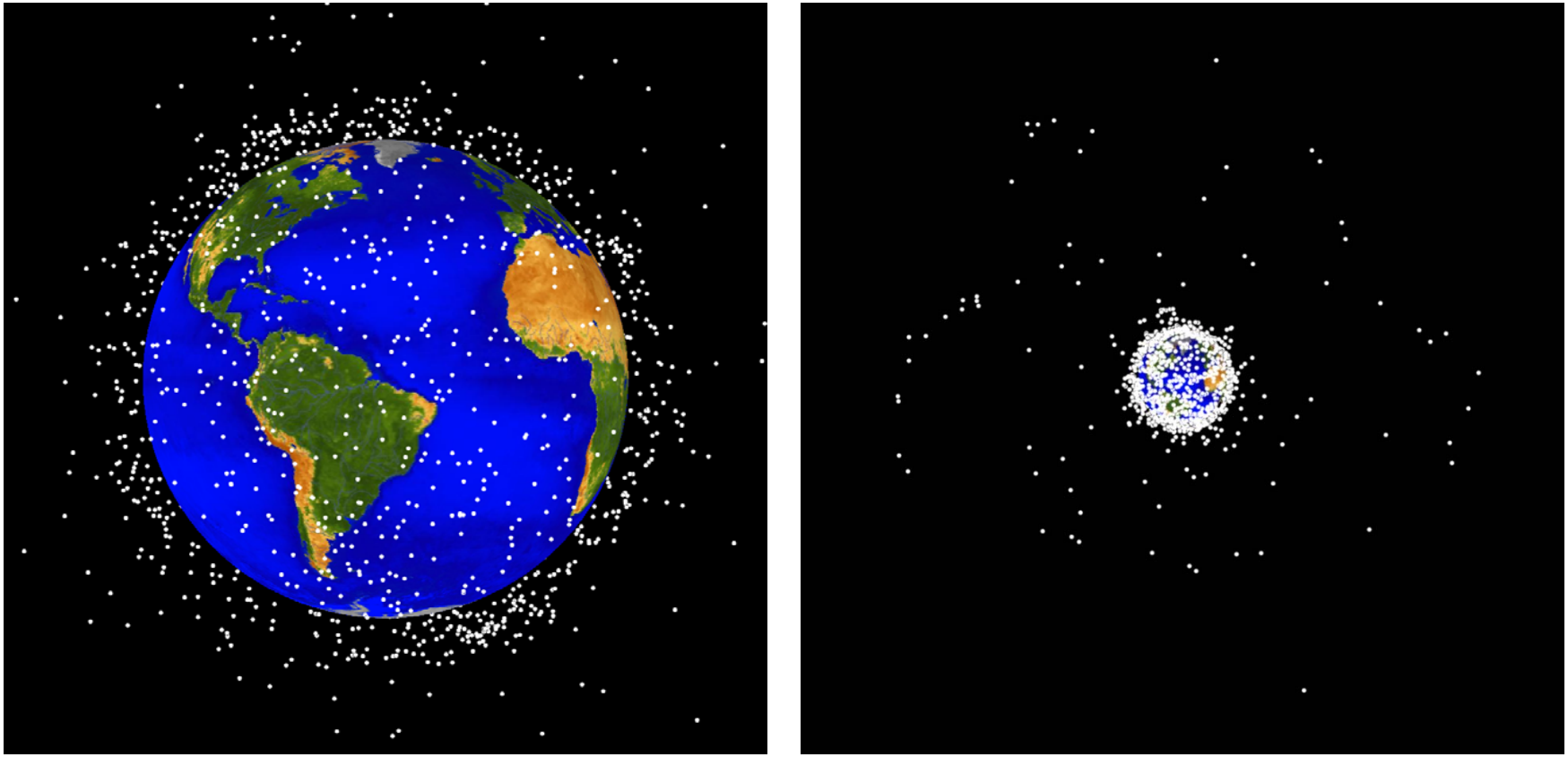
1965



Cataloged objects >10 cm diameter

Growth of the Earth Satellite Population

1970



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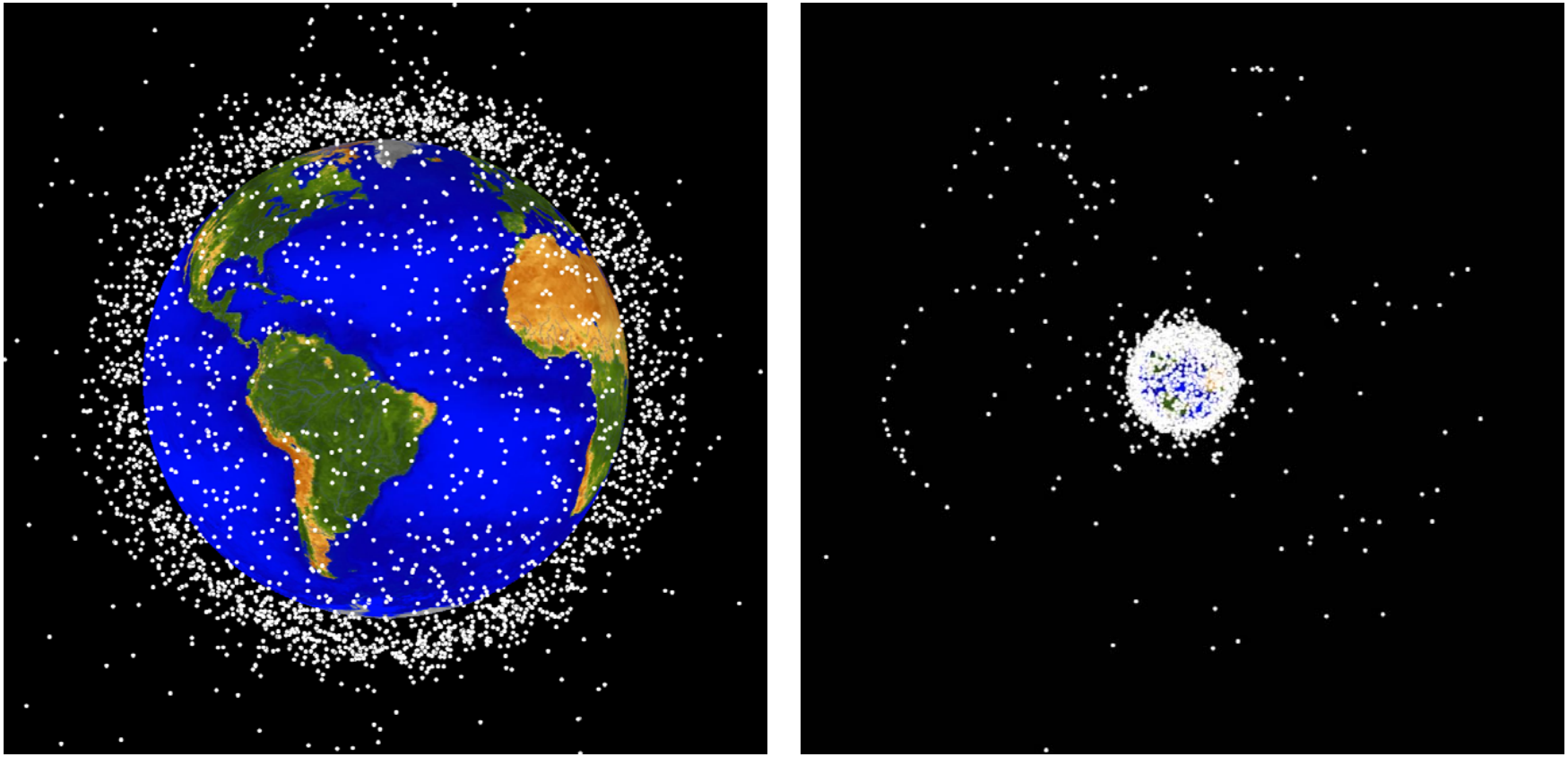
Growth of the Earth Satellite Population

1975



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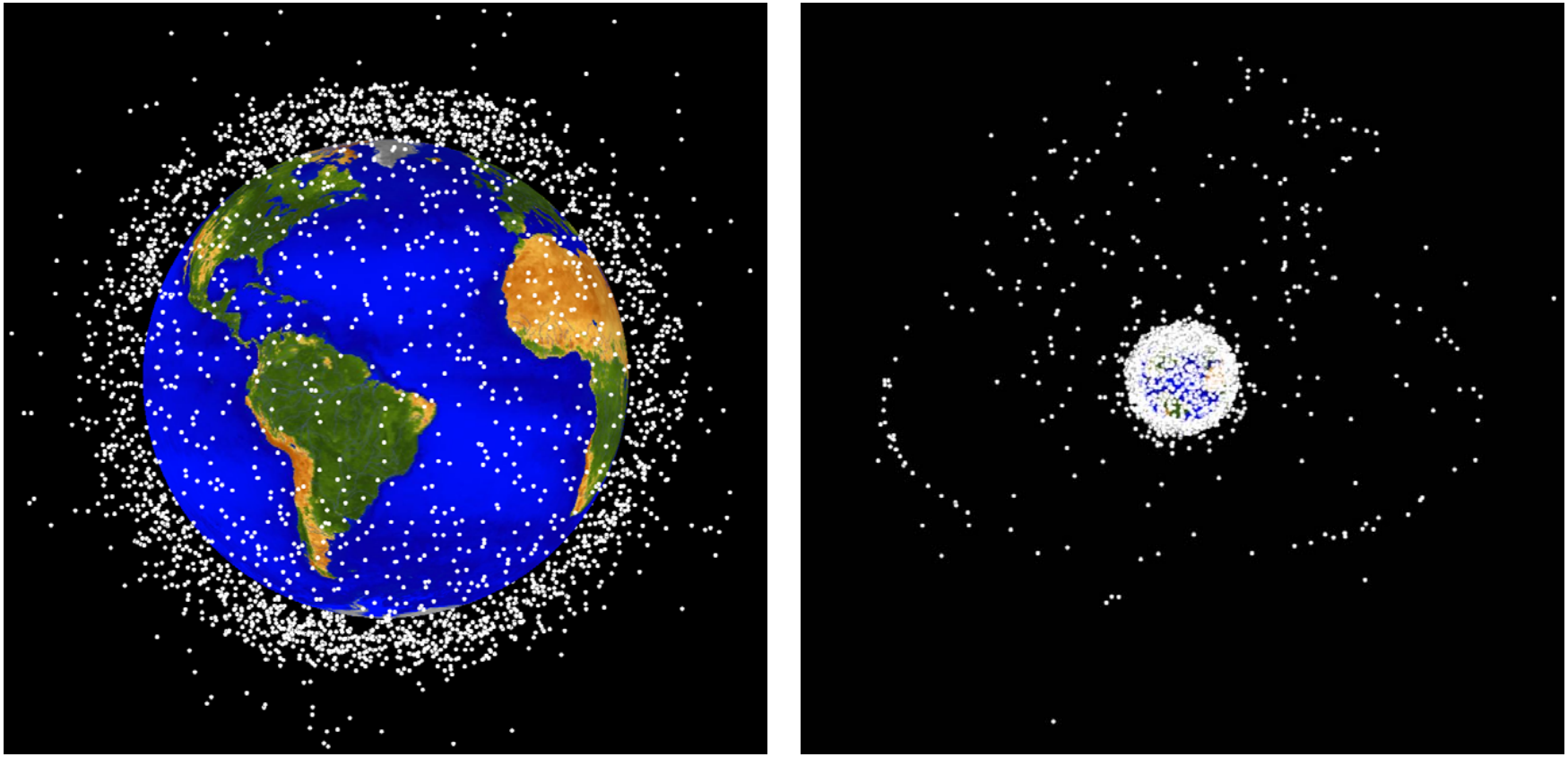
Growth of the Earth Satellite Population

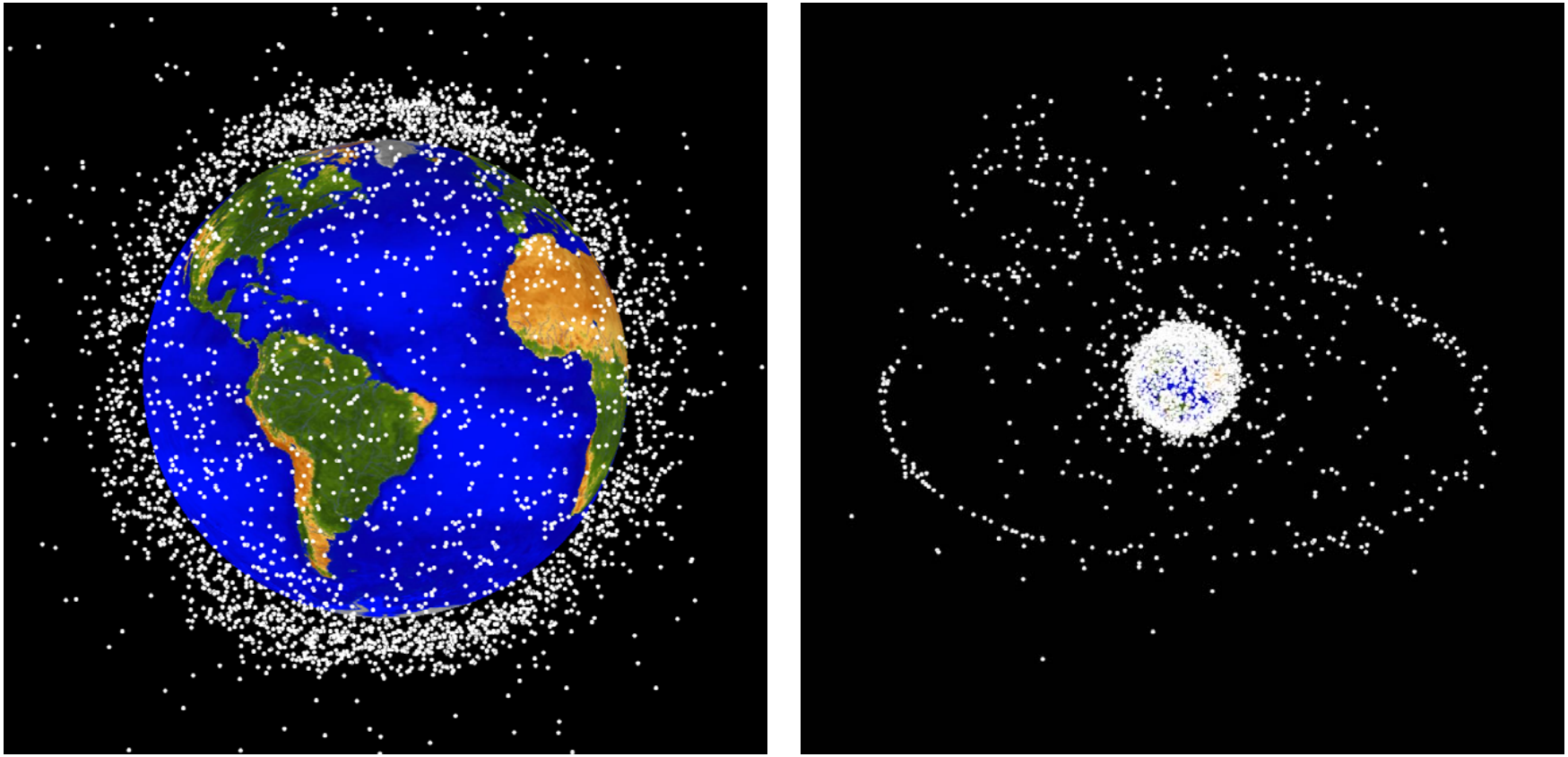
1980



Cataloged objects >10 cm diameter

Growth of the Earth Satellite Population

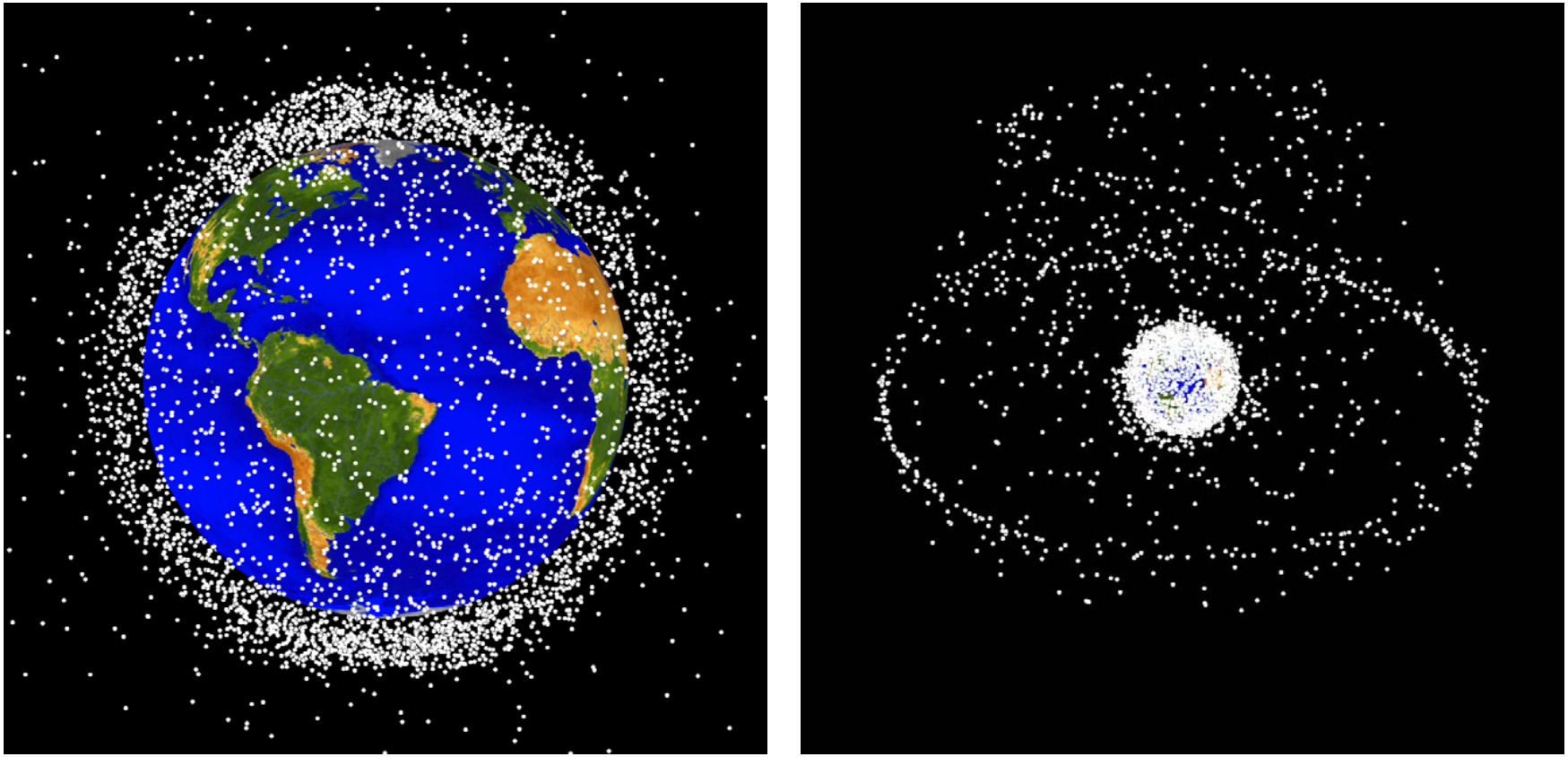
1985



Cataloged objects >10 cm diameter

Growth of the Earth Satellite Population

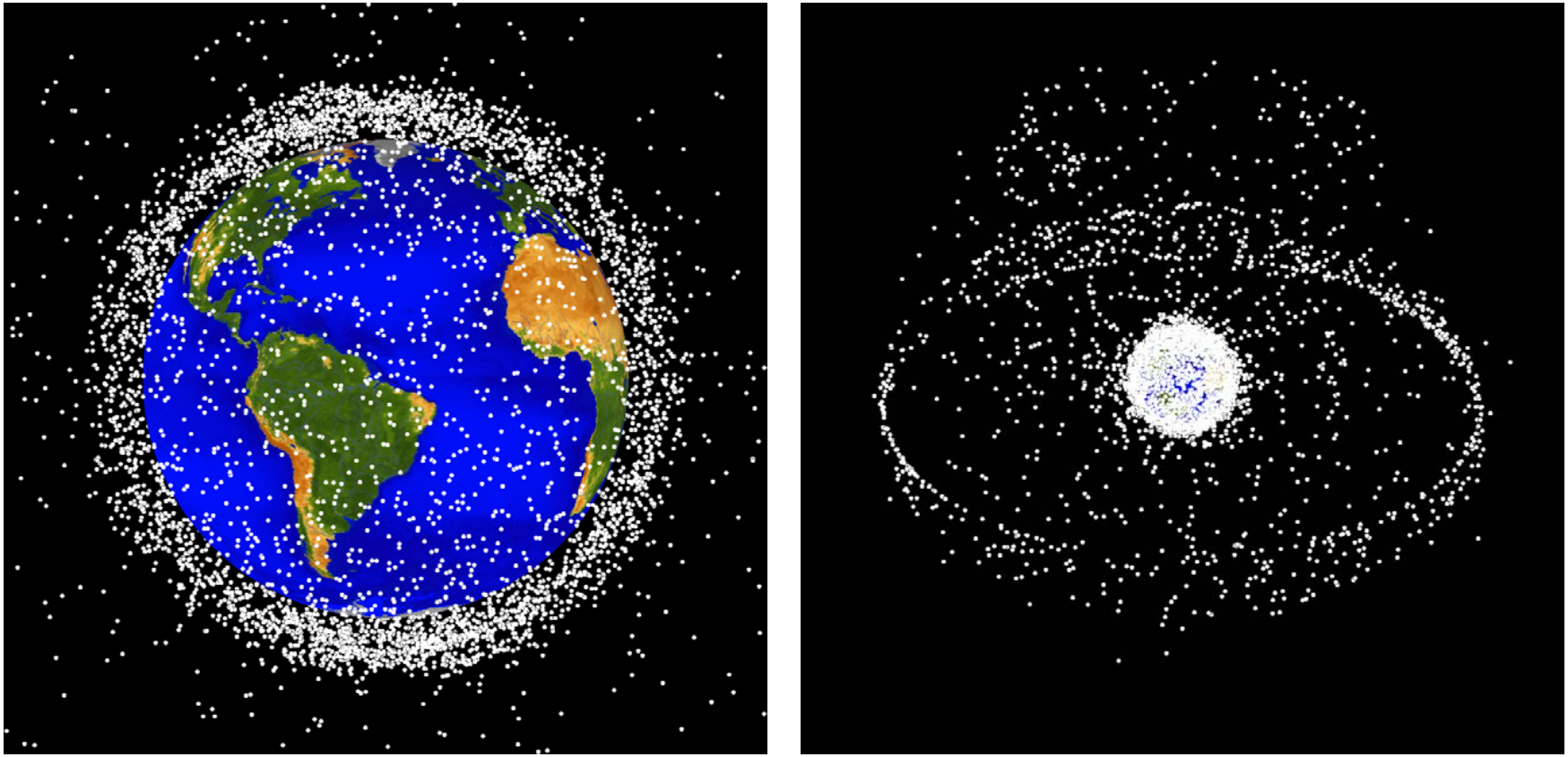
1990



Cataloged objects >10 cm diameter

Growth of the Earth Satellite Population

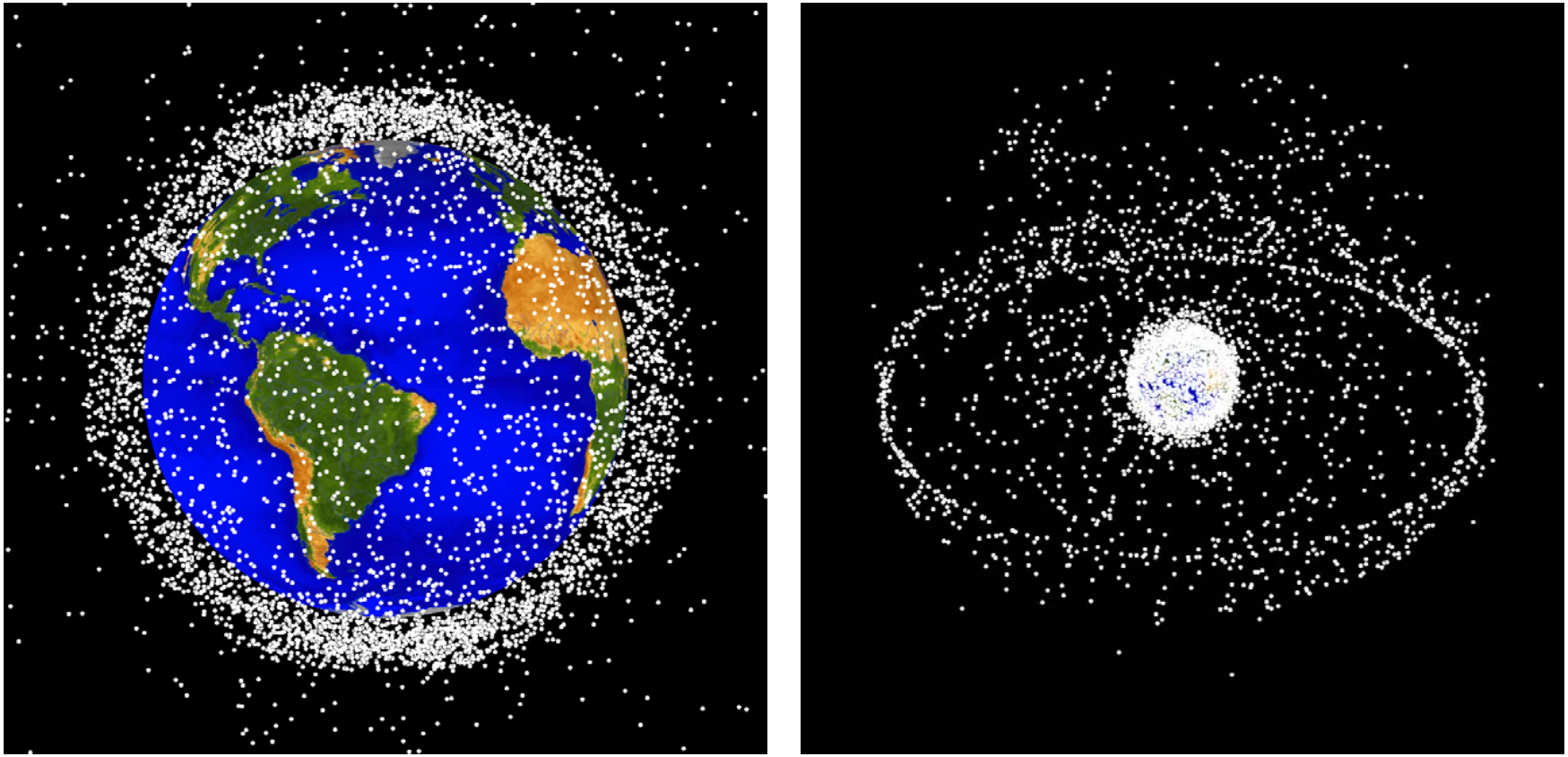
1995



Cataloged objects >10 cm diameter

Growth of the Earth Satellite Population

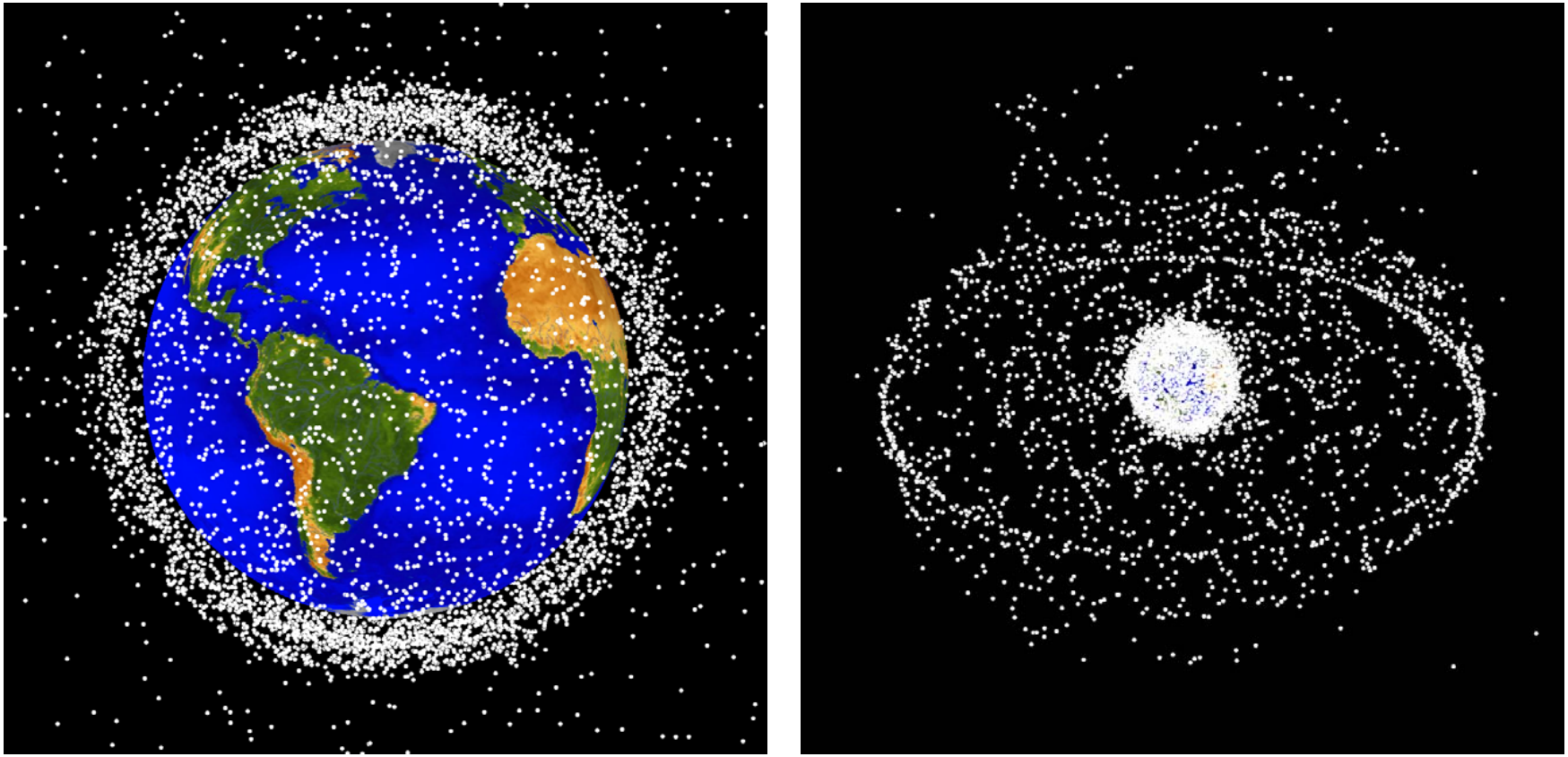
2000



Cataloged objects >10 cm diameter

Growth of the Earth Satellite Population

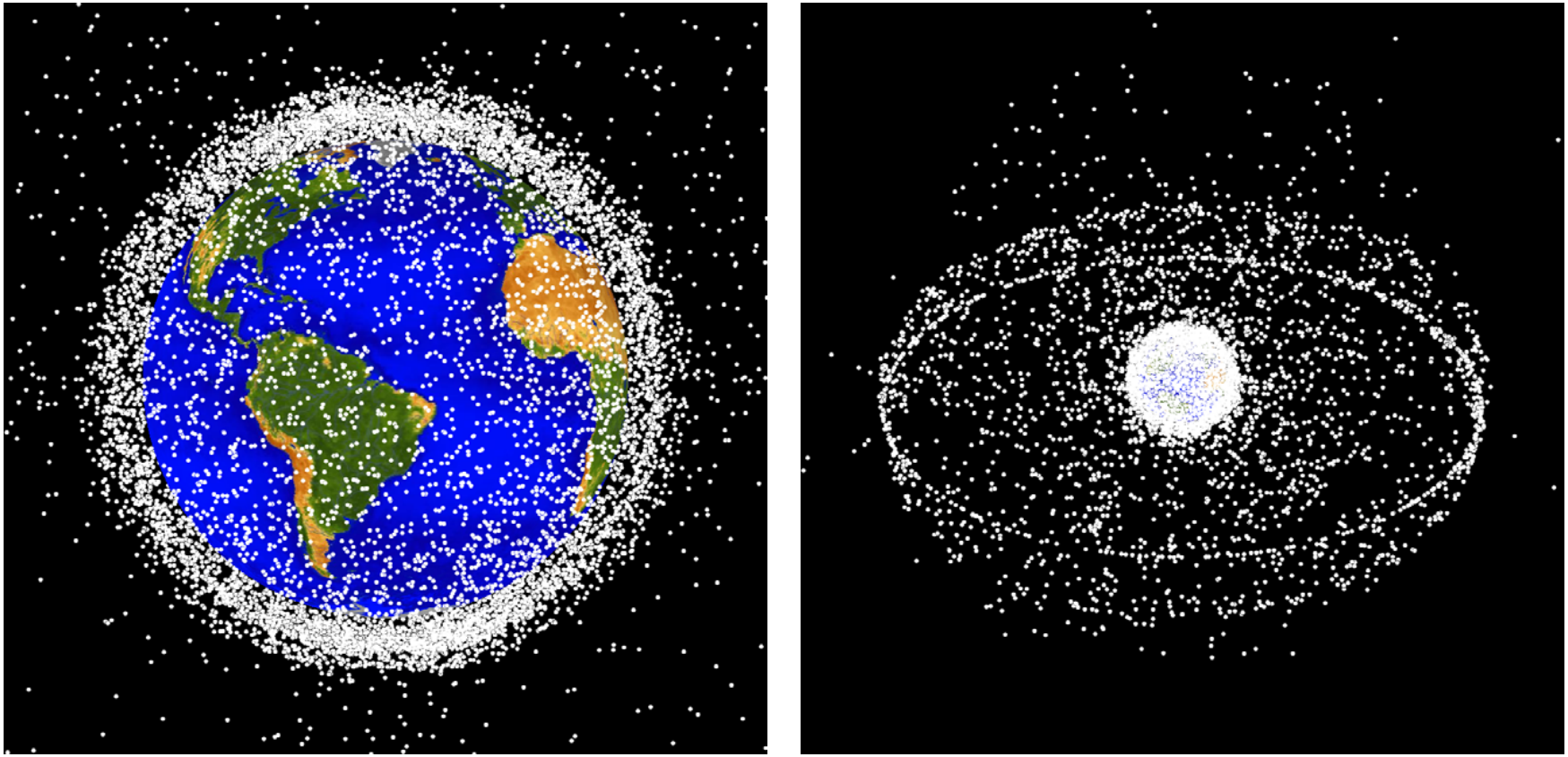
2005



Cataloged objects >10 cm diameter

Growth of the Earth Satellite Population

2010



Cataloged objects >10 cm diameter

Why Orbital Debris Mitigation?

- **U.S. has endorsed the United Nations' *Orbital Debris Mitigation Guidelines***

- **President's National Space Policy directs agencies and departments to implement *U.S. Government Orbital Debris Mitigation Standard Practices***

To preserve near-Earth space for future generations

NPR 8715.6A

and

NS 8719.14A

NPR 8715.6A

- **NASA Procedural Requirements for Limiting Orbital Debris, NPR 8715.6, was approved in August 2007 and replaced NASA Policy Directive 8710.3B**
  - Highest level NASA document on orbital debris mitigation
- **Orbital Debris Assessment Reports are required in conjunction with the Preliminary Design Review and Critical Design Review milestones**
  - Format and content of the reports are set forth in NASA Standard 8719.14A
- **Chapter 3.3 of NPR 8715.6A sets requirements for end-of-mission planning and execution, including**
  - Passivation of spacecraft designed for reentry into Earth's atmosphere or for disposal about the Earth or the Moon;
  - Avoidance of lunar disposal orbits; and
  - Examination of potential lunar landing or crash sites.

NASA Standard 8719.14A

- **NASA Standard 8719.14 replaced NASA Safety Standard 1740.14 in August 2007. Revised as NS 8719.14A in December 2011.**
  - Specifies orbital debris mitigation requirements and performance standards.
  - First change in 12 years.
- **NASA Standard 8719.14A contains detailed directions on how each Orbital Debris Assessment Report (ODAR) and each End-of-Mission Plan (EOMP) shall be prepared.**
  - Spacecraft and launch vehicle topics are separated for ease of preparation.

Requirements

- **Limits on debris released during normal operations**

- **Requirement 4.3-1a:** All debris released during the deployment, operation, and disposal phases shall be limited to a maximum orbital lifetime of 25 years from date of release

- **Requirement 4.3-1b:** The total object-time product shall be no larger than 100 object-years per mission.

- **Requirement 4.3-2:** Debris passing near GEO: For missions leaving debris in orbits with the potential of traversing GEO (GEO altitude +/- 200 km and +/- 15 degrees latitude), released debris with diameters of 5 cm or greater shall be left in orbits which will ensure that within 25 years after release the apogee will no longer exceed GEO - 200 km

Requirements

- **Limiting debris generated by explosions and intentional breakups**

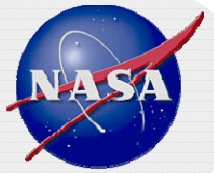
- **Requirement 4.4-1:** Limiting the risk to other space systems from accidental explosions during deployment and mission operations while in orbit about Earth or the Moon

- **Requirement 4.4-2:** Design for passivation after completion of mission operations while in orbit about Earth or the Moon

- **Requirement 4.4-3.** Limiting the long-term risk to other space systems from planned breakups

- **Requirement 4.4-4:** Limiting the short-term risk to other space systems from planned breakups

Requirements



- **Limiting debris generated by generated by on-orbit collisions**
- **Requirement 4.5-1:** Limiting debris generated by collisions with large objects when operating in Earth orbit
- **Requirement 4.5-2:** Limiting debris generated by collisions with small objects when operating in Earth or lunar orbit
- **Postmission disposal of space structures**
- **Requirement 4.6-1:** Disposal for space structures in or passing through LEO
- **Requirement 4.6-2:** Disposal for space structures near GEO

Requirements

- **Limiting surviving debris from Earth atmospheric reentry**
- **Requirement 4.7-1:** Limit the risk of human casualty

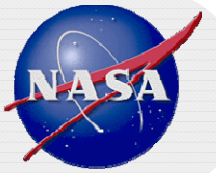
- **Limiting risks associated with space tethers**
- **Requirement 4.8-1:** Mitigate the collision hazards of space tethers in Earth or Lunar orbits

Handbook for Limiting Orbital Debris

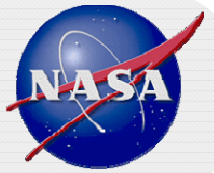
- **The *Handbook for Limiting Orbital Debris* is a new type of NASA document for orbital debris mitigation.**

- **The handbook, NASA Handbook 8719.14, provides additional technical background information on a wide variety of orbital debris environment and mitigation topics.**

- **The handbook is divided into seven major sections:**
  - Current Orbital Debris Environment
  - Future Environment
  - Measurements of the Orbital Debris Environment
  - Modeling the Orbital Debris Environment
  - Micro-Meteoroid and Orbital Debris Shielding
  - Mitigation
  - Reentry



Back-up Slides



NASA Debris Assessment Software (DAS)

Introduction

- **The NASA Debris Assessment Software (DAS) is actually a set of custom tools designed to assist space programs and projects in preparing orbital debris assessment reports.**
  - Assessment requirements are described in NASA Standard 8719.14, “Process for Limiting Orbital Debris”
  - DAS 2.0 addresses most requirements point-by-point

- **Reasons for the upgrade to DAS 2.0 are numerous, including:**
  - Issuance of NS 8719.14 to replace NSS 1740.14, *i.e.*, changes in debris mitigation guidelines
  - Improvements to the orbit propagators and debris environment model
  - Improvements to the reentry survivability model and casualty estimation method
  - Improvements to the user interface and documentation
  - Improvements to personal computers, *e.g.*, operating systems and capabilities
  - Recommendations from users of the early versions of DAS

- **Download software and reference materials at:**

  http://www.orbitaldebris.jsc.nasa.gov/mitigate/das.html

User Interface

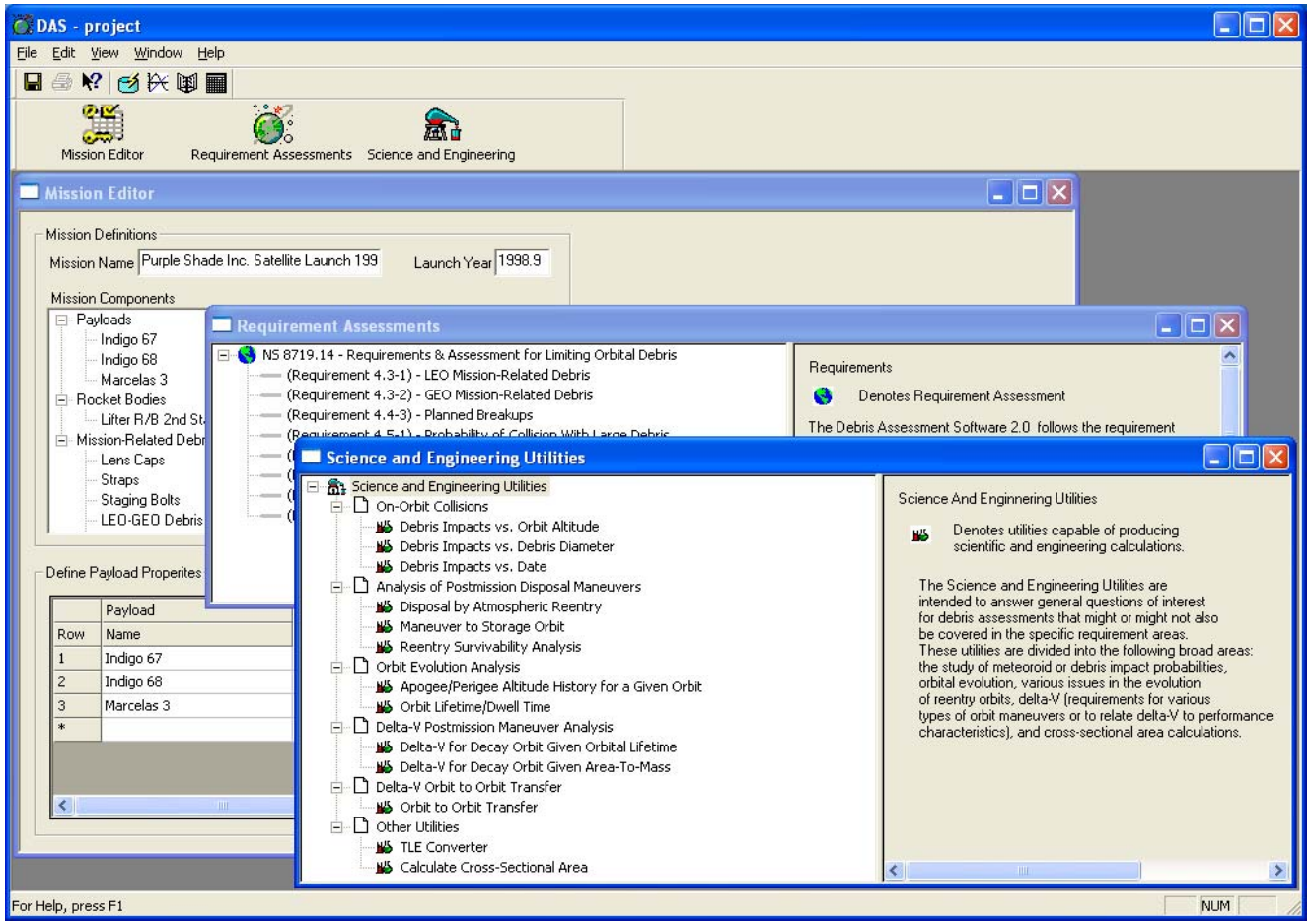
- **Microsoft Windows User Interface**
  - DAS 2.0 uses a “native” Windows graphical user interface (GUI)
  - Runs on Windows 2000, XP, Vista, and Windows 7
  - The GUI consolidates user input and avoids long chains of menu

- **“Project” Orientation**
  - DAS 2.0 saves the user’s input and output files as a “project” in a single directory
  - Other files and directories are not affected by the projects
  - Moving or sharing a project is as simple as moving or sharing the project directory

- **Division of Modules**
  - Mission Editor
  - Requirement Assessments
  - Science and Engineering Utilities
  - Supporting features

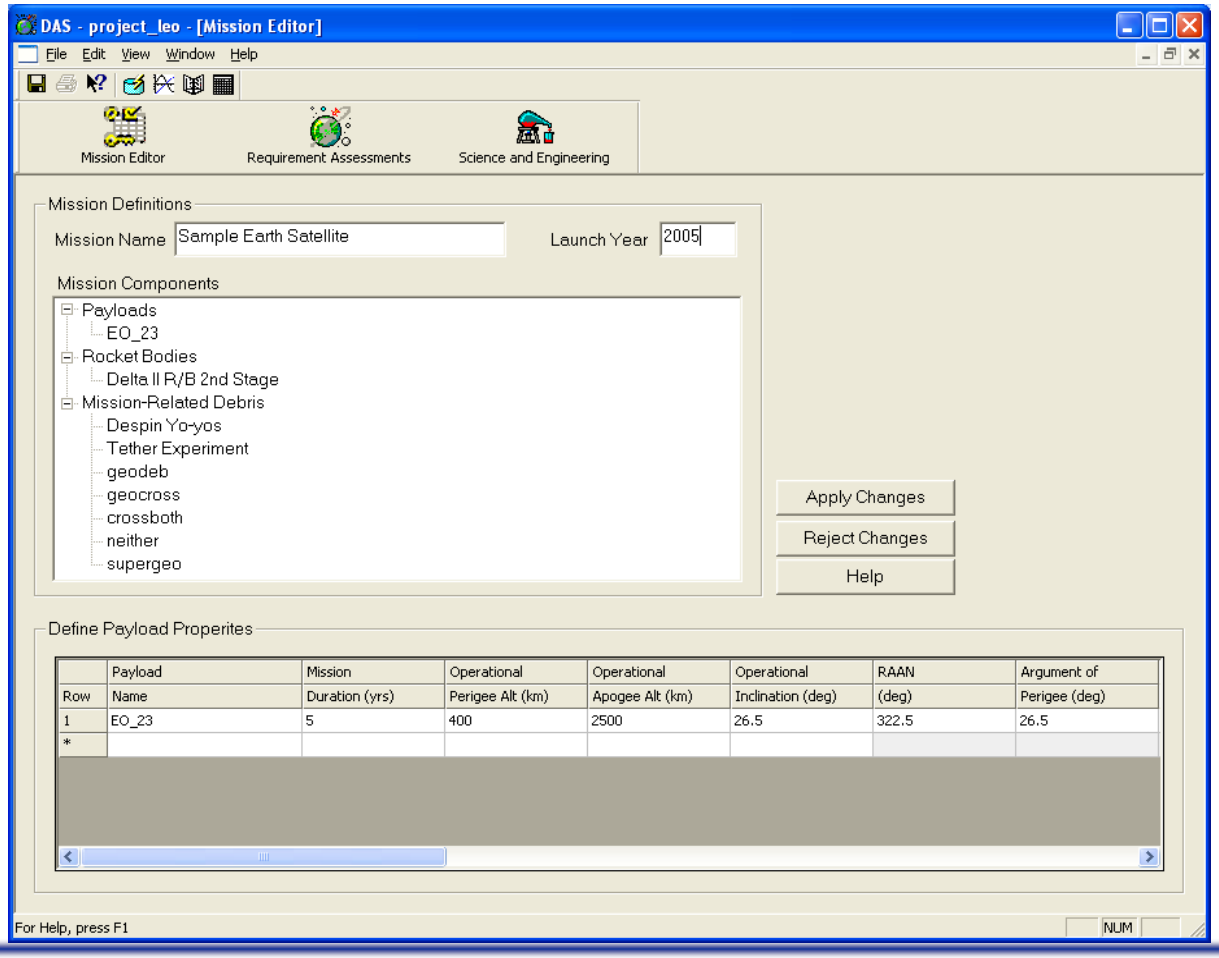
DAS 2.0 User Interface

The DAS 2.0 top-level window, and three main dialog windows

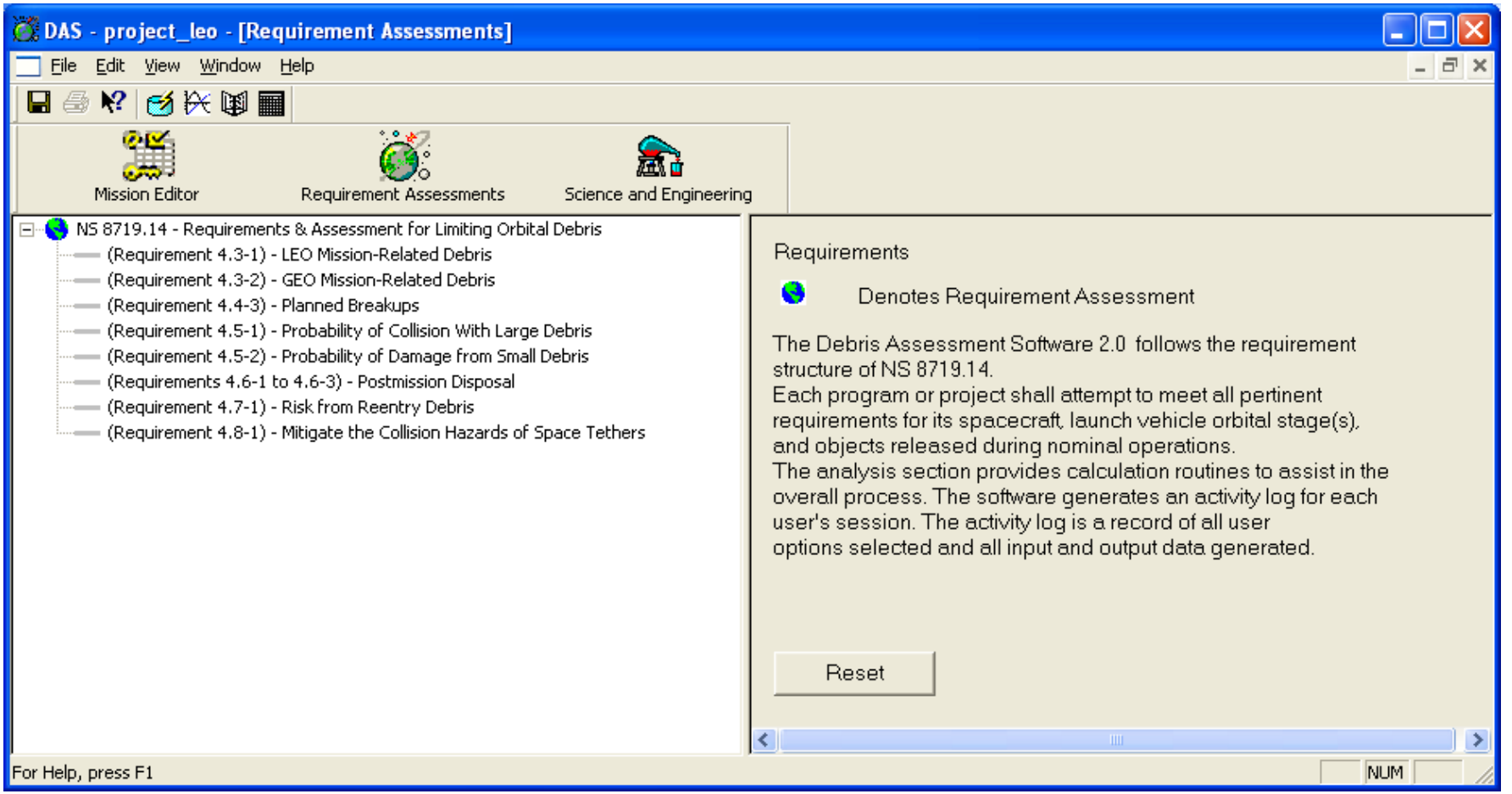


GUI: Mission Editor

- **The user enters most of the mission information into the Mission Editor**
- **Most assessments are complete using only the information in the Mission Editor**



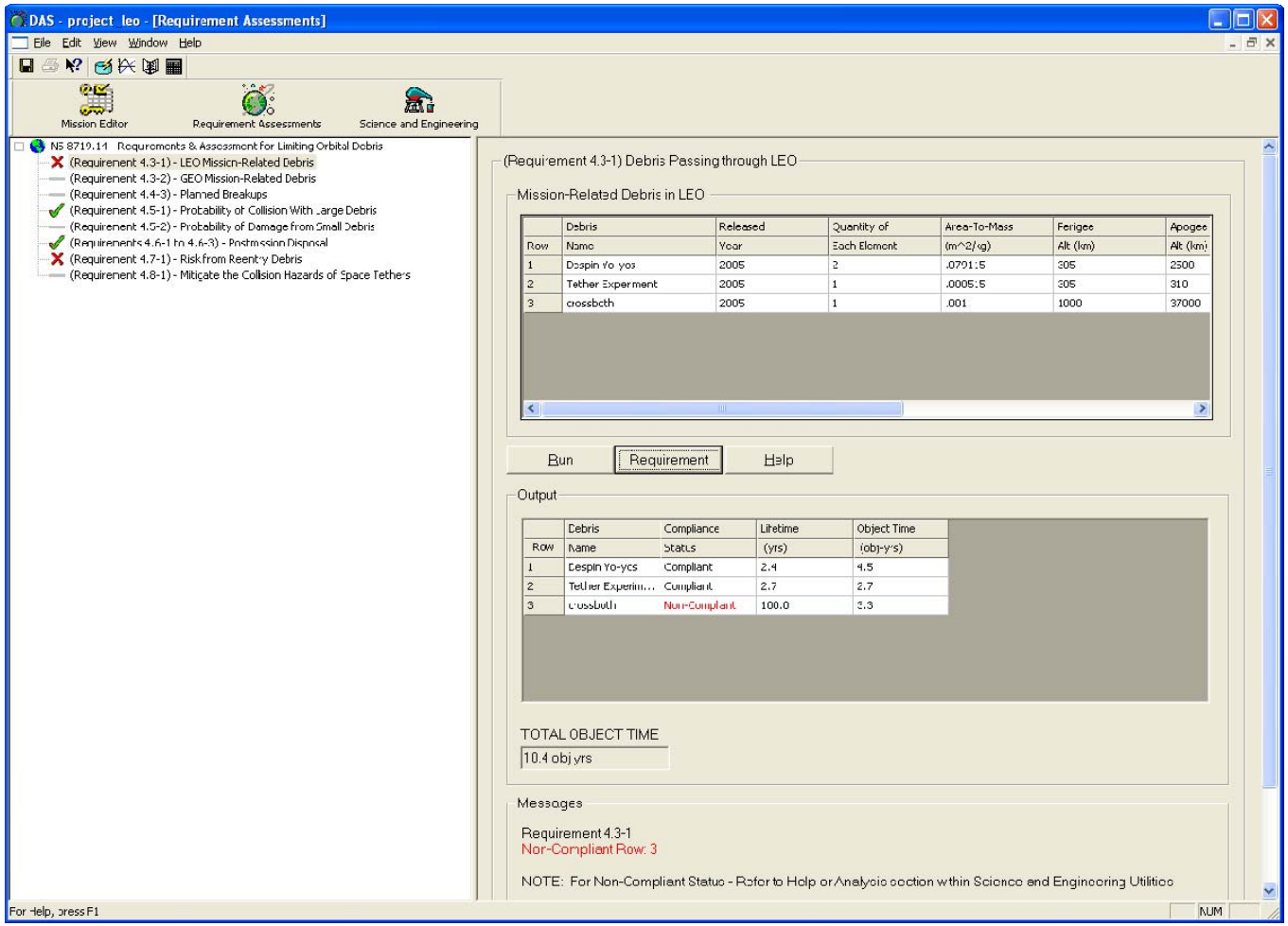
GUI: Requirement Assessments



The user may assess the mission's compliance with each requirement

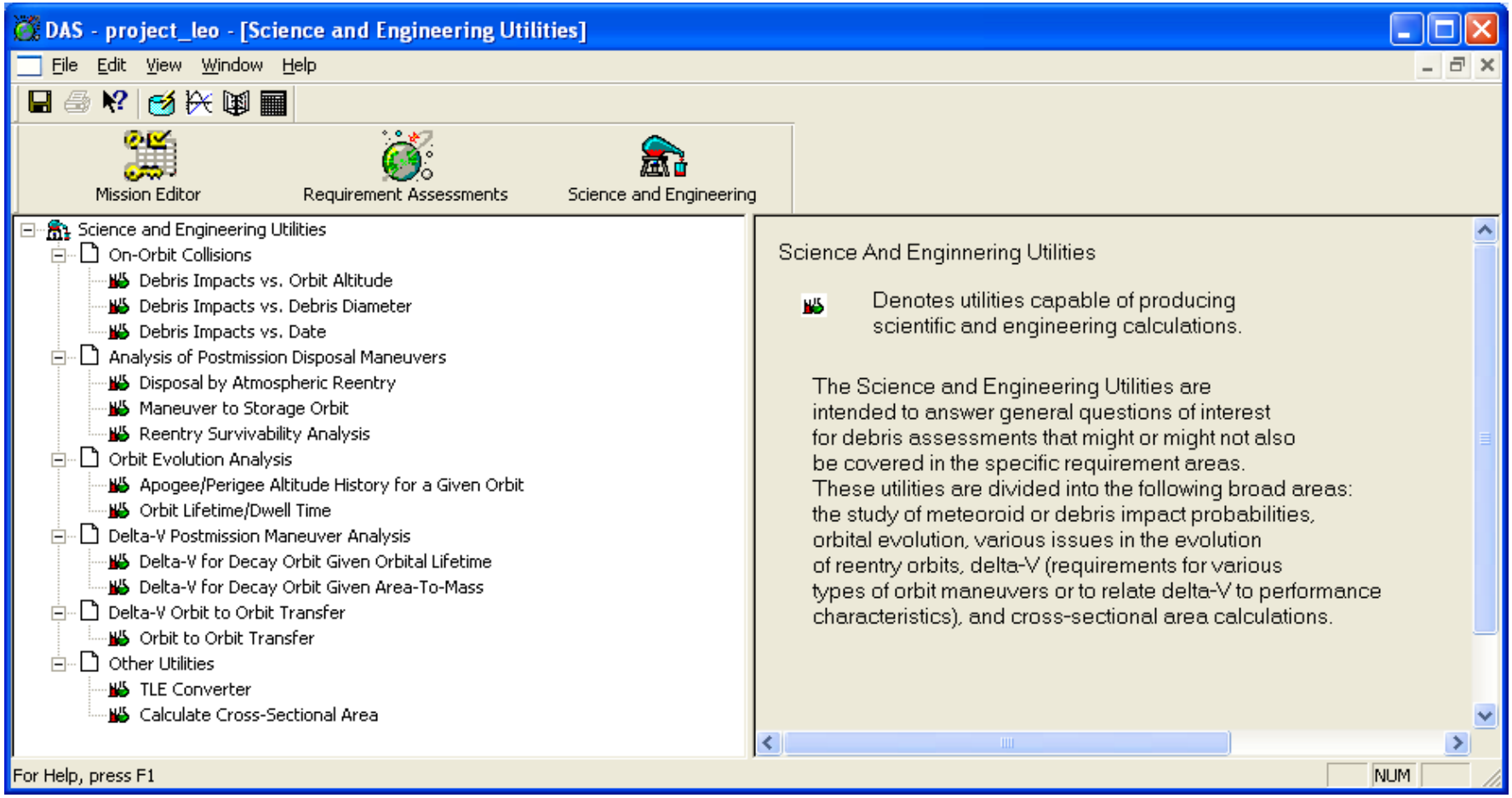
GUI: Sample Requirement Assessment

The right-hand pane shows inputs, outputs, and compliance status



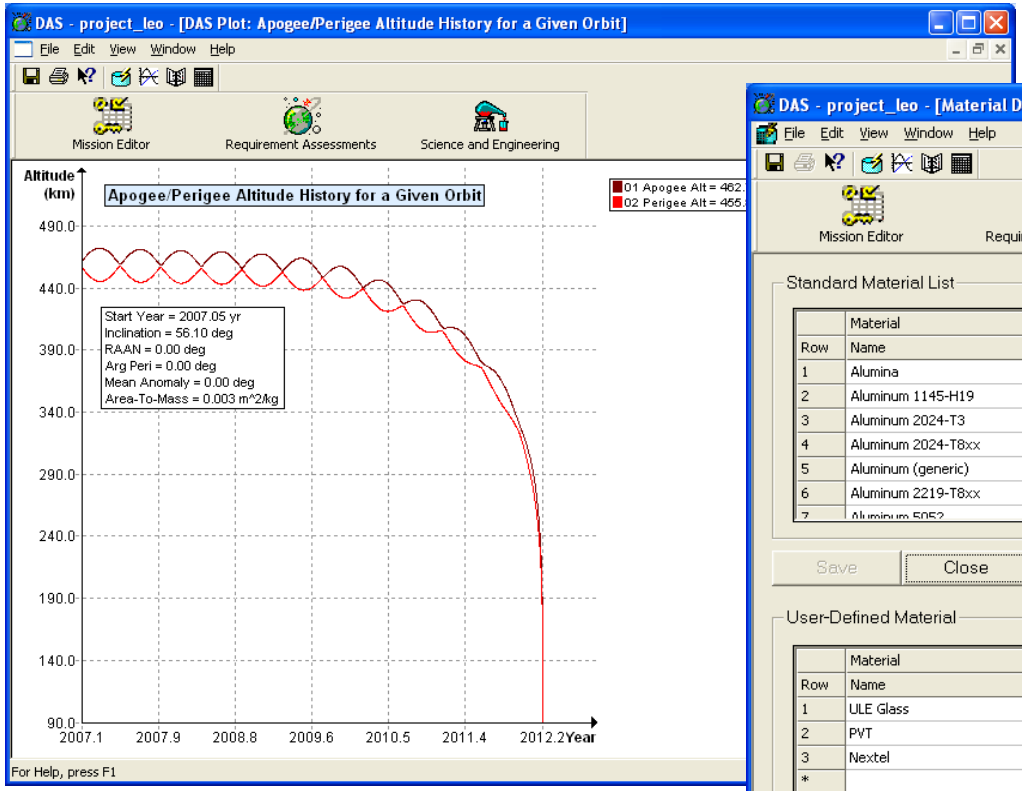
GUI: Science and Engineering Utilities

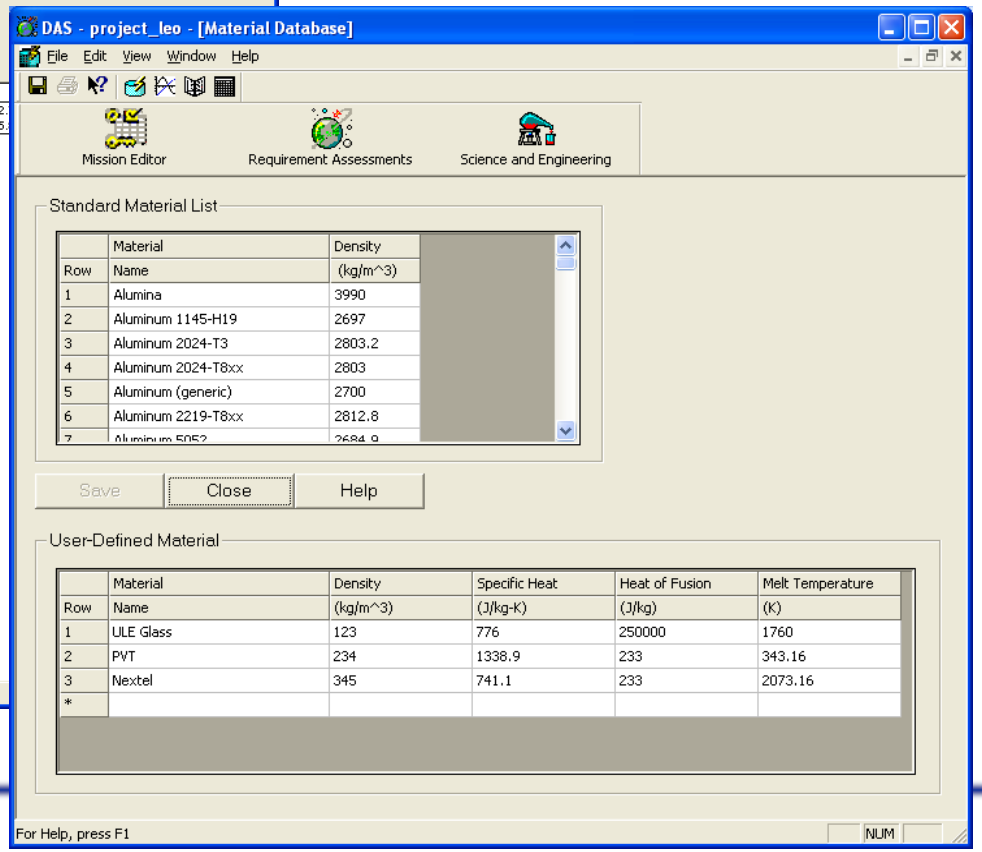
These utilities allow the user to explore options in mission design and to perform other supporting calculations



GUI: Other Supporting Features

- **Customizable plots**
- **Material properties database**
- **Text activity log**
- **Date conversion tool**





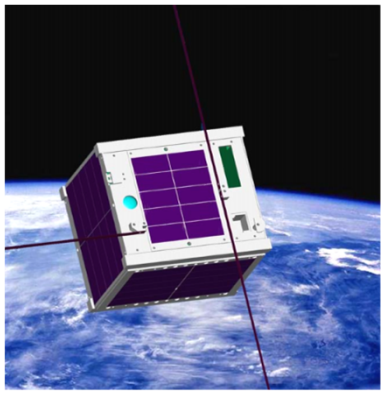
Summary

- **DAS is the standard method of assessing compliance with NASA's space debris mitigation requirements (NS 8719.14A).**
  - DAS provides point-by-point assessment of a mission's compliance with NASA's requirements.
  - Results from DAS may be included in reports to NASA.
  - DAS provides additional tools for mission-planning and input conversion.
- **The modular internal structure of the software allows for easy updates (such as to the debris environment model or the human population density) in the future. Solar activity forecasts are updated quarterly.**
- **Software and documentation are available on the NASA Orbital Debris Program Office's internet site:**

http://www.orbitaldebris.jsc.nasa.gov/mitigate/das.html

Non-operational Spacecraft

- **More than 6800 spacecraft have been placed into Earth orbit since Sputnik 1 in 1957**
- **Currently, >3400 spacecraft remain in Earth orbit**
  - ~1000 are operational; the rest are orbital debris
- **Small: Picosats and Microsats**
  - Operational lifetimes typically months to a few years
- **Large: Geosynchronous spacecraft**
  - Operational lifetimes typically a decade or more

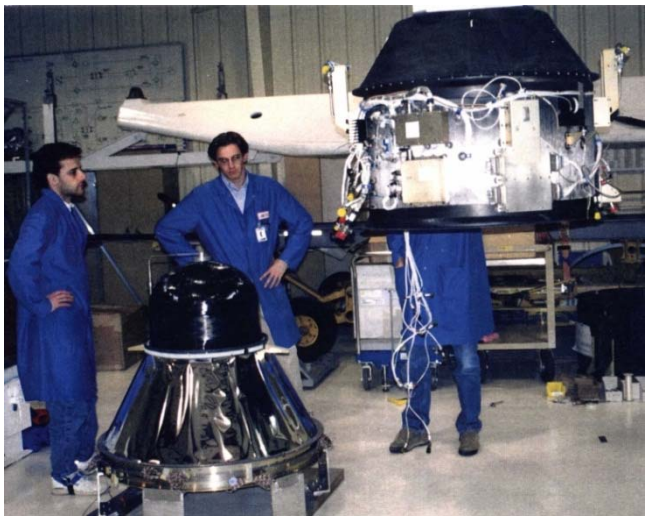


Cubesats: 1 kg

TDRS 1: 2 metric tons

Launch Vehicle Stages

- More than 5400 launch vehicle stages have been placed into Earth orbit since Sputnik 1 in 1957
- Currently, ~1700 launch vehicle stages remain in Earth orbit
- Sizes range from <100 kg to 9 metric tons



Pegasus upper stage

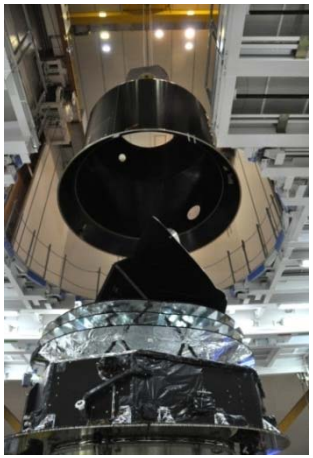
Atlas V Centaur stage

Mission-related Debris

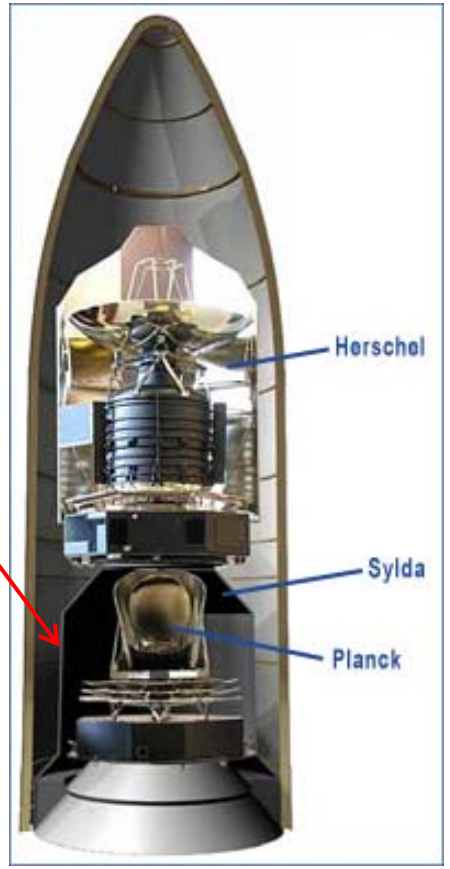
- **During the launch and satellite deployment processes, some debris can be generated, e.g., sensor and engine covers, straps, springs, and yo-yo despin weights**

- **Most spacecraft and launch vehicles are now designed to eliminate or limit the generation of mission-related debris**

  – One exception is for multiple payload launches, *e.g.*, Ariane and Delta 2



Ariane 5 SYLDA Payload Dispenser



Fragmentation Debris

- **The majority of debris in Earth orbit have originated from the fragmentation of spacecraft and rocket bodies.**

- **Fragmentation events can generally be classified in one of three categories:**

  – Anomalous events: Typically one or a few debris released at low velocities, often possessing higher than normal area-to-mass ratios. Many of these debris have short orbital lifetimes. More than 100 events identified with spacecraft and upper stages.

  – Explosions: Intentional or accidental, resulting in only a few to several hundred large debris and many more smaller debris. Ejection velocities range from very low to very high for a single event. Two hundred events identified.

  – Collisions: Also can be intentional or accidental. Debris distributions similar to explosions. Two major events since 2007.

Accidental Satellite Collisions

- **Four known accidental hypervelocity collisions between cataloged objects.**
  - 1991: Cosmos 1934 struck by piece of mission-related debris
  - 1996: CERISE struck by piece of Ariane 1 fragmentation debris
  - 2005: U.S. upper stage struck by piece of Chinese upper stage fragmentation debris
  - 2009: Collision of Iridium 33 and Cosmos 2251 spacecraft
- **The first three events created very few debris. The collision of Iridium and Cosmos 2251 resulted in more than 2000 large (trackable) debris and many more smaller debris.**
- **A few low velocity collisions have also occurred during operations but have resulted in no or few debris, e.g., Progress-M 34 and the Mir Space Station.**